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The representation of tropical cyclones in high resolution coupled climate simulations

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Tropical cyclones (TCs) are one of the most impactful weather phenomena on Earth. Their formation and development depends on small-scale processes like air-sea interaction and convection. These processes pose challenges for climate models since they are often misrepresented and act as sources of uncertainty. Additionally, TCs interact with both tropical and extratropical large-scale circulation, contributing to the upscale error propagation. The accurate representation of such physical processes in climate models therefore is crucial for the correct simulation not only of TCs but of the entire climate system. Until a few years ago, these small scale processes could not be resolved explicitly in traditional state-of-the-art coupled climate simulations due to a too coarse horizontal resolution. Nowadays that we are able to run climate simulations at a very high resolution (less than 10 km) and explicitly resolve such processes we expect to have a much more realistic representation of the intensity, frequency, and structure of TCs in climate models.

For this study, we consider data from the nextGEMS and Climate Digital Twin (part of the Destination Earth initiative) experiments (with an horizontal resolution up to 2.5 km), assessing model performance comparing them with both ERA5 reanalysis and with observational data sets such as IBTrACS to detect model biases. An algorithm for the detection and tracking of TCs based on the TempestExtremes library is used to detect and track TCs at first on a coarser resolution grid on a single time step (e.g., every 6 hours). Then, a series of variables at the original model resolution are saved in the vicinity of the TC centres, to allow examining their finer structure with an unprecedented level of detail. This diagnostic is part of the Application for Quality assessment and Uncertainty quAntification (AQUA) model evaluation framework developed within the Destination Earth project. Our analysis considers the TCs intensity (e.g. cyclones classification, wind pressure relationship), TCs structure (e.g. examining wind gusts and rain bands) and TCs temporal and spatial distribution (computing and analysing TCs trajectories). Preliminary results enlight the ability of these very high-resolution climate simulations to represent TCs features in a much more realistic way, especially close to the smallest resolved scales. Moreover, an increased horizontal resolution is beneficial to reduce model biases, enabling climate models to simulate TCs with a magnitude comparable to the observations.